SEMIANNUAL REPORT

National Aeronautics and Space Administration

Grant NsG-419

Covering the Period

October 15, 1964-April 15, 1965

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August 11, 1965

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This Semiannual Report covers the period from October 15, 1964, to April 15, 1965, during which research was performed under National Aeronautics and Space Administration Grant NsG-419. Progress in the three principal areas of investigation is briefly reviewed below.

1. K-Band Radiometry

From May to August, 1964, extensive observations of the radio emission from Venus, the moon, the sun, and the terrestrial atmosphere were made with a multi-channel microwave radiometer operating at 21.1, 21.9, 23.5, 25.5, 29.5, and 32.4 Gc/s. This data has been largely analyzed and interpreted, and has yielded very interesting results. The results of much of of this work are contained in the Doctoral dissertation of David H. Staelin and are being submitted for publication in the Astrophysical Journal.

The microwave spectrum of Venus appeared to dip in the region of 1.3-cm wavelength, and the magnitude of the dip appeared to vary over the period of the observations. This result is consistent with the results of other observers, and appears to be a real phenomenon. The most plausible explanation for such a dip is the presence of resonant absorbers in the atmosphere of Venus, the most likely candidate being water vapor. Several spectra are presented in Table 1. Preparations are underway for similar observations during the inferior conjunction January, 1966.

TABLE 1

Frequency (Gc/s)	Average Brightness Temperature (^{o}K) June 5-12	June 29-July 16	July 27-30 / July 15-18	Average, entire experiment
32.4	425 $\pm$ 33^{o}K	446 $\pm$ 38^{o}K	436 $\pm$ 57^{o}K	430 $\pm$ 24^{o}K
29.5	444 $\pm$ 59	470 $\pm$ 55	334 $\pm$ 148	463 $\pm$ 32
25.5	464 $\pm$ 33	415 $\pm$ 23	401 $\pm$ 40	428 $\pm$ 20
23.5	447 $\pm$ 50	443 $\pm$ 40	504 $\pm$ 91	450 $\pm$ 23
21.9	384 $\pm$ 54	389 $\pm$ 49	504 $\pm$ 83	404 $\pm$ 28
21.1	—	—	500 $\pm$ 82	502 $\pm$ 82

The errors are the estimated standard deviations of the relative values of the measurements. The final results will be published in the near future.

Measurements of terrestrial atmospheric opacity were made by means of solar extinction observations. These were made on 10 days, and six measurements were accompanied by radiosonde flights launched nearby. The measured atmospheric spectra are in good agreement with theory, and show that such microwave measurements not only can yield the integrated amount of water vapor in the atmosphere, but also information about its distribution with altitude. The amplitude of the water vapor absorption was observed to fluctuate a factor of two during the experiment. Similar measurements accompanied by radiosondes are currently underway at frequencies of 21.9, 22.235, 23.5, 29.4, and 32.4 Gc/s, and should yield approximately 30 days observations during June-August, 1965. Theoretical studies of means for inverting the microwave data to obtain estimates of the water vapor profile and the integrated cloud density are well underway.

Fifteen lunar experiments comprising 375 drift scans were made over two lunation periods, and include maps of the lunar brightness temperature, and polarization measurements.

The data was fit by a lunar surface of dielectric constant 1.7 ± 0.1, and 15° rms deviation of facet normals. A rougher surface would imply a higher dielectric constant. The brightness temperature of the lunar center is best described by:

$$T_B = 220 + 29 \cos (\omega t - 48^\circ) + 12 \cos (2\omega t - 35^\circ) \pm 6^\circ K \quad 25.5 \text{ Gc/s}$$

$$T_B = 220 + 24 \cos (\omega t - 43^\circ) + 10 \cos (2\omega t - 38^\circ) \pm 3^\circ K \quad 21.9 \text{ Gc/s}$$

where the data has been normalized to 220°K, and the harmonics content was determined using measurements of the slopes of the lunar brightness temperatures. The results are consistent with those of the other observers at other wavelengths, but are not well matched by current theoretical models, which predict a second harmonic approximately half that determined here and elsewhere. The lunar results are contained in a thesis submitted to the Department of Electrical Engineering by James M. Moran, Jr. in partial fulfillment of the requirements for the Master of Science degree. These results are being prepared for publication.

II. Oxygen-Line Observations at High Altitudes

Work on the 5 mm oxygen lines has continued. Two balloon experiments at 100,000 feet were undertaken. Observations were made in three frequency bands, 20, 60, and 200 mc from the 9+ transition frequency, and at zenith angles of 60° and 75°. For these flights a data telemetry system was operating, which permitted monitoring the data as the flight progressed. The first of the two flights was only partially successful due to a switch failure. The second flight was totally successful, yielding useful data for the duration of the flight. The results of these flights differ from the theoretical calculations in a manner that cannot be explained within the framework of the Van Vleck-Weisskopf line shape. The results of previous partially successful flights also show this effect. A series of three more flights with greater sensitivity is planned for the summer of 1965.

The theoretical investigation of the inclusion of the Zeeman effect into the 5 mm analysis is largely complete. A matrix method for handling the propagation of partially-polarized waves was developed and applied to the Zeeman split oxygen lines in the upper atmosphere. A set of computer programs was written that computes the brightness temperature matrix at satellite heights for a nadir angle of 0°. The brightness temperature matrix contains a complete specification of the polarization of the radiation.

Studies have been made and are continuing to investigate the effect on the received brightness temperature of position (latitude and longitude), magnetic field model, temperature profile model, receiver bandwidth, and receiver polarization. These will be viewed in terms of possible satellite experiments to remotely probe the atmospheric thermal profile.

III. Millimeter Equipment

During the period of this report, work continued on the 4 mm parametric amplifier and solid-state power generation. Investigations were also carried out on broadband rf transformers and other aspects of rf components.

The 2 mm klystron was finally delivered and some preliminary investigations of the new parametric amplifier structure were carried out. Studies of doping materials and techniques with the new 1 micron GaAs epitaxial stock were started, but the results cast suspicion on the available power output of the 2 mm klystron. Checks with a calorimeter show the output power to be 3 db less than specified. However, a doubler from 4 mm to 2 mm was tried, using the present 4 mm paramp structure, and an indicated power output of 3 mw was obtained with a nominal (less than 50 mw) drive.

Experimental work on solid-state sources included further careful measurement of varactor parameters using a potentiometer and equal-incremental c technicques to achieve .01% accuracy. Several multipliers have been built using designs based on the measurements and on recent theoretical results. One such multiplier gave 2w out at 5.5 Gc for 3w drive at 2.75 Gc and had no tuning adjustments; theoretically, diode efficiency should have been 70%, agreeing well with observed values of 66%. Important, new theoretical results will be available next quarter, based on work carried on during this quarter.

Many aspects of broadband rf transformers have been studied. New ferrite materials and new techniques allow autotransformers to be built with 10:1 impedance ratios and frequency ranges from 10 kHz to 200 MHz. The new autotransformer technique together with more conventional transmission-line transformers makes possible very wideband linear amplifiers of considerable power output (watts to kilowatts).

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